A Method for Decisions Among Freeway Location Alternatives Based on User and Community Consequences

CLARKSON H. OGLESBY, BRUCE BISHOP, and GENE E. WILLEKE,
Department of Civil Engineering, Stanford University

This paper proposes a method that can be used in decision-making among freeway location alternatives in urban areas and that incorporates both user and community consequences. It also proposes a step-by-step procedure that can both systematize and simplify the decision-making process. The proposed method presents a list of user and community factors as a basis for analysis. These are separated into (a) the direct economic effects and (b) the community effects. In order to make the community effects more understandable, a graphical procedure called the factor profile is offered as a tool for analyzing them. In addition, tentative numerical measures for quantification of community factors and an indication of the effect of the factors over time are suggested. The method of decision-making is a series of paired comparisons and uses engineering economic analysis and factor profiles. When 2 alternatives are compared, the incremental costs or benefits from the economic analysis are weighed against the differences in community impact between the alternatives as shown by the factor profiles. An attitude survey of highway planners, community officials, and citizens showed the importance of recognizing different viewpoints in the analysis. Comparisons should therefore be made from the viewpoint of each group in the community and these preferences considered in making the final decision. The factor identification and factor profile approach can also be a useful tool during the planning process in defining factors important to community groups, establishing goals, and developing alternatives.

•CONSEQUENCES TO USERS and impacts on affected communities are both recognized as important parts of decisions about urban freeway locations. Often, of course, these decisions are made primarily in response to political pressures without a systematic evaluation of any kind. Highway planners and analysts have proposed various methods for evaluating these factors in order to provide a basis for improving and expediting the decision-making process. These techniques can be divided into 2 groups. Those in the first group apply economic measures such as the benefit-cost ratio. They are primarily based on agency costs and motor vehicle operating and, possibly, time costs. The other techniques use some form of point weighting scheme similar to the sufficiency rating. Seldom does either method include more than a few of the many variables relevant to the decision.

A general criticism of either approach is that it has failed to recognize 2 basic principles of decision-making: (a) Decisions must be based on the differences among alternatives; and (b) money consequences must be separated from the consequences that are not reducible to money terms, and then these irreducibles must be weighed against

Paper sponsored by Committee on Socio-Economic Aspects of Highways and presented at the 49th Annual Meeting.

the money consequences as a part of the decision-making process (3). One of several statements that apply these principles to highways and freeways is the following (4):

> In many cases, some consequences of decisions among highway alternatives cannot be expressed in terms of money. Furthermore, these "irreducibles," "to whomsoever they may accrue," are relevant to the decision. In these situations, the "dollar" answers from the economy study do not dictate the final choice; on the other hand they provide a money figure against which the irreducibles can be weighed and thereby narrow the area of uncertainty with which the decision maker is faced.

This paper proposes and discusses a procedure that is intended to fit these rather simple statements of principle to the complex problem of decision-making among proposed freeway locations in urban areas. It offers a structure and analytical tools by which valid comparisons among alternatives can be made.

It must be recognized at the outset that decisions about urban freeway locations usually involve a variety of effects that are viewed and weighted differently by the affected groups. At the same time the human mind can at one time encompass and analyze the effects of only a limited number of such relationships. Thus a primary aim of any decision-making scheme must be to eliminate as many irrelevant factors as possible, and to provide a means for clearly focusing on and thinking straight about the remaining areas of agreement as well as on the points of disagreement.

REVIEW AND CRITIQUE OF PRESENT METHODS OF ANALYSIS

The present methods for making decisions among alternative freeway locations can be generally divided into 2 groups. These are benefit-cost or other economy studies and point weighting schemes. A brief review and critique of each of these approaches follows.

Benefit-Cost Studies

Engineering economy provides the basis for comparing the direct economic consequences of alternate route locations with each other or with the "do nothing" alternative, which, in this instance, is to continue to use existing facilities. Engineering economic analysis has taken the following forms: benefit-cost ratios including incremental benefit-cost ratios, present worth of benefits minus present worth of costs, equivalent uniform annual cost, and rate of return including incremental rates of return. These methods are presented and discussed by various writers (4, 13, and others). All of the methods, when correctly applied, will give equivalent answers. These techniques have been little used, except on the Interstate System where they were required by the Bureau of Public Roads. Even these studies often left much to be desired (5).

The principal difficulties in benefit-cost studies for alternative highway locations in rural areas relate to such factors as estimating future traffic volumes, choosing a proper time period for the analysis, determining appropriate unit values for such items as time, and specifying the minimum attractive rate of return. Each of these problems has received attention in the literature (13). In the urban environment, freeways have additional consequences referred to in the literature as community impacts or effects. These often involve values that cannot be quantified in money terms. Neither suitable techniques nor adequate data have been developed for appraising the economic effects of these factors; furthermore, it may be inappropriate to quantify some of them. It follows that, in the urban context, economic analysis may give only a partial appraisal of the problem.

Factor Weighting Methods

Systems of point weightings and numerical ratings also have been proposed as a method for evaluating community impacts. The approach of Jessiman et al. (8) is to itemize the objectives to be considered in the selection of the location and, where possible, to define a measure for the objective. Each objective is given a weight that reflects its importance relative to the other objectives. A total of 100 percent is assigned to all the objectives. Points are given to each proposal according to how well it satisfies the objective; the one best satisfying each objective receives the maximum points allowed, the worst receives none, and the remainder are assigned values between zero and the maximum. Points allotted to each objective are totaled for each proposal, and the one achieving the most points is considered the best alternative.

Hill (7) proposes a similar evaluating method that he calls a goal achievement matrix. This provides for separate weightings by individual segments of the community; in turn, these opinions are weighted to reflect the relative importance of each group. Other methods of analysis have been suggested by Roberts (9), Shimpeler and Grecco (11), and Schlager (10).

All of these weighting methods violate in some basic way the 2 principles of decision-making stated earlier. Some of the reasons for this deficiency and some of the difficulties encountered in attempting to consolidate community effects into a single number are as follows:

1. Finding common units of measure. The first difficulty is in finding a common unit for constructing a utility scale that can measure all the diverse impacts of a freeway in such a way that they can be combined into a single number.

2. Assigning the values. Any procedure that requires the assigning of subjective numerical values leads to the question of who is to assign them. Clearly, where conflicting interests are involved, the viewpoint taken will affect the values assigned. Careful observation of planning studies reveals that values change during the planning process. This is to be expected as the natural result of information developed by the study itself and by the planners' reactions to this information. It follows that the rating scheme itself becomes another variable in the planning process.

3. Weighting the interest groups. Even if adequate evaluations by various groups can be obtained, the problem of comparing the evaluations or utilities assigned by one individual or group with those of others and deciding how much weight should be given to each still exists. Different members of society have different interests. Inevitably they will value the various objectives at widely varying rates. While the theoretical concept of utility is important, it is severely limited by the fact that no way has been demonstrated to measure the utilities of all individuals on some absolute scale. Until such interpersonal comparisons of utility are possible, the aggregation of the preferences of all individuals and groups in society into a single measure cannot be taken to be an objective measuring device.

4. Determining the amount of information needed for complex decisions. In any situation where large amounts of information must be encompassed in a decision, the tendency of decision-makers is to aggregate all information relevant to the decision into a single number. Too much information is confusing, but too little information or an overaggregation of information can lead to incorrect decisions. Too much aggregation submerges pertinent information. It masks and covers the true differences among alternatives and leaves no way to identify and contract these differences in decision-making. A middle ground is needed where the number of factors in the decision is manageable, and yet all the differences among the alternatives that are pertinent to the decision are shown.

USER AND COMMUNITY FACTORS IN EVALUATING ROUTE LOCATION ALTERNATIVES

To carry out an engineering, economic, and social analysis of the effects of freeway location requires that a basis be established for evaluating both user and community consequences when comprehensive comparisons are made of the differences among alternatives. To accomplish this requires that 3 important aspects of the problem be considered: (a) quantification and separation of user and community factors, (b) viewpoint of decision-makers, and (c) time period of analysis. Decision-makers should include all of these in their analyses if optimal decisions are to be made.

Quantification

Comparisons of the differences among alternatives depends on defining the factors that measure the relative merits of the alternatives. Identification and quantification of these factors are difficult problems. Tables 1 and 2 represent the effort of the authors to develop a list of factors that describe the cost of the freeway and its impact on users and the community. These tables separate the consequences into direct and indirect effects in a manner which, in the authors' opinions, is best in keeping with the second principle of decision-making and with the best current practice in highway economy studies. Table 1 gives the direct effects that are specifically associated with highway construction and use, and Table 2 gives the indirect effects that fall on the nonuser and the community. The measures or suggested measures indicate whether these consequences are currently quantifiable in money terms, or, in other instances, those factors for which there seems to be a good possibility to measure them in some other units. Factors that are seemingly nonquantifiable also are noted. The word nonquantifiable is used advisedly because the effects described by the item are real. In time they might be quantified, though not necessarily in dollar values.

User and Direct Effects—Table 1 gives the items of direct cost of the highway and costs or benefits to the highway user. Items 1 and 2 are those typically used in the calculation of benefits and costs in the economic analysis of highway projects. The variables listed under item 1 and item 2a are readily definable and, given reasonably accurate inputs, are quantifiable in money terms. The same is not true, however, for item 3 and item 4. These are important in the ledger of costs and benefits to the tripmaker. Considerable research effort has been devoted to arriving at monetary values for some of these factors. There remains, nevertheless, substantial controversy and disagreement as to the methods for imputing values to these factors, the values to be assigned, and whether or not certain portions of them should be considered at all (1, 2, 6, 12).

In order to avoid confusion, and also to place the analysis on a solid economic basis, the authors recommend that only the quantifiable market values (measurable in the marketplace) stated in money terms be included in the economic analysis. This means that travel time savings must be divided into commercial and noncommercial (Table 1) segments and a monetary value used only for commercial travel time. Likewise, only

TABLE 1

DIRECT EFFECTS OF FREEWAY CONSTRUCTION AND USE

Factor	Description	Units	Time Period, Years
Quantifiable market values			
1. Cost of highway			
a. Planning	Capital cost and annual cost of planning, constructing, maintaining, and operating the freeway	Dollars	N. A.
b. Right-of-way		Dollars	20 to 40
c. Construction		Dollars	20
d. Maintenance		Dollars	Annual
e. Operation		Dollars	Annual
2. Costs (benefits) to highway user			
a. Vehicle operating cost, including congestion costs	Net increase (decrease) in costs of vehicle operation per year	Dollars	Annual
b. Travel time savings, commercial	Net increase (decrease) in travel time multiplied by dollar value of commercial travel time	Dollars	Annual
c. Motorist safety, economic cost of accidents	Net change in expected number of accidents multiplied by average cost per accident	Dollars	Annual
Quantifiable nonmarket values			
3. Costs (benefits) to highway user			
Travel time savings, noncommercial	Minutes saved per vehicle trip	Minutes or hours	Annual
Nonquantifiable nonmarket values			
4. Costs (benefits) to highway user			
a. Motorist safety	Accident costs of pain, suffering, and deprivation	?	Annual
b. Motorist comfort and convenience	Discomfort, inconvenience, and strain of driving	?	Annual
c. Aesthetics from driver viewpoint	Benefit of pleasing views and scenery from the road	?	Annual

TABLE 2

COMMUNITY EFFECTS OF FREEWAY LOCATION AND USE

Factor	Measures and Suggested Measures: Description	Units	Time Period: Long Run	Time Period: Short Run
Local Transportation Effects				
Traffic service to community by freeway-highway capacity, O-D of trips, major traffic generators	1. Percent reduction of through traffic on city streets [(vehicles before - vehicles after)/ vehicles before]	Percent	x	
	2. Distance of freeway access from major traffic generators (e. g., academic, business, cultural, administrative centers) or as measured by road user or transportation costs	Miles	x	
	3. Corridor miles compatible with present or future public transportation development	Miles	x	
Effect on local transportation: city street circulation and public transit	1. Costs (savings) for improvement to city streets to provide for projected traffic volumes if freeway is not built	Dollars	x	
	2. Net change in parking space available as result of freeway	No. spaces	x	
	3. Number of interchanges with the community less streets closed	Number	x	
Access to regional facilities: recreation, education, culture, business, and employment	1. Travel time savings to regional activity centers [(minutes per vehicle) x (vehicles per day)] for each facility	Minutes per day	x	
	2. Number of trips to community generated from outside	Vehicles per day	x	x
Highway design standards: grades, alignment, and interchange location	1. Miles less than x percent grade	Miles	x	
	2. Miles of curvature less than y radius	Miles	x	
	3. Average distance between interchanges	Miles	x	
Community Planning and Environment				
Land use: land development, changes in use, multiple use, separation of uses	1. Land for potential development to which access is created	Acres	x	
	2. Miles of freeway separating incompatible land use minus miles dividing compatible uses	Miles	x	
	3. Miles adjacent to or through land undergoing change in use	Miles per acre	x	
Aesthetic impact of freeway on community: depressed or elevated, landscaping, structures	1. Miles depressed in residential areas plus miles elevated in commercial areas less miles at grade	Miles	x	
	2. Additional costs of aesthetic improvement in structures and landscaping	Dollars	x	
Noise	1. Increase in dB level weighted by miles residential, and numbers of schools, churches, and similar buildings adjacent to freeway	dB (weighted)	x	
	2. Additional cost of noise barriers in noise problem areas	Dollars	x	
Air pollution	1. Net change in noxious exhaust emissions for projected traffic with and without the freeway	Percent	x	
Neighborhood and Social Structure				
Property values: changes in resale values	1. Increase or decrease (net) over normal trend in property value classified by type of use and distance from freeway	Dollars	x	
Neighborhood impacts: displacement and relocation of people, environmental qualities, neighborhood cohesiveness and stability	1. Number of housing units displaced (or) number displaced as percent of community's total stock	Number Percent	x x	x x
	2. Number of people displaced (or) number displaced as percent of community's population	Number Percent	x x	x x
	3. Net loss of housing—units taken less vacant replacement housing in same price range with comparable financing less new construction planned on vacant land with financing	No. units	x	
	4. Cohesive neighborhoods severed by freeway (as determined by mapping neighborhood boundaries and social characteristics)	No. people	x	x
	5. Neighborhood stability (14, pp. 33-42)	Index No.	x	x
Parks and recreational facilities	1. Acres of parks lost (gained) as percent of total available acres	Percent	x	
	2. Cost of park replacement less compensation	Dollars	x	
	3. Number of parks affected	Number	x	x
Cultural and religious institutions	1. Number of churches taken (or) total attendance affected	No. churches No. people		x x
	2. Additional cost of relocation, excess over taking price	Dollars	x	
	3. Improved access or location for new church facilities	Minutes	x	
Historical sites and unique areas	1. Number of historical areas lost (total affected less those relocated)	Number	x	
	2. Value of monument measured by annual visits per year	Visits per year	x	

TABLE 2 (Continued)

COMMUNITY EFFECTS OF FREEWAY LOCATION AND USE

Factor	Measures and Suggested Measures: Description	Units	Time Period: Long Run	Time Period: Short Run
School system: attendance boundaries, school environment	1. Net loss (gain) in tax base for school system	Dollars	x	x
	2. Number of schools totally or partially taken (or affected)	Number		x
	3. Number of school attendance areas with access to school seriously impaired where boundaries cannot be adjusted	No. pupils	x	x
	4. Increase (decrease) in cost of providing school services because of changes in busing	Dollars	x	x
	5. Net additional cost to the community of relocating schools affected by freeway (plus) cost of noise reduction in schools adjacent to freeway	Dollars	x	
Community Economic and Fiscal Structure				
Effect on tax base: Net change in assessed value of property on tax rolls	1. Loss of assessed valuation in right-of-way as percent of community total	Percent		x
	2. Loss of assessed valuation in right-of-way less increase of land values (assessed) caused by freeway impact	Dollars	x	x
	3. Net loss (gain) in tax revenue caused by freeway impact	Dollars	x	x
Community services: police and fire protection, utility services, water and garbage services	1. Net increase (decrease) in costs of providing fire and police protection and water, sewerage, and garbage service	Dollars	x	
Commercial activity: wholesale, retail	1. Net increase (decrease) over normal trend in gross wholesale and retail sales	Dollars	x	
	2. Net number of businesses located (displaced) by freeway	Number		x
Employment: creation of jobs, displacement of jobs	1. Net number of jobs located (displaced) as a result of freeway	Number		x
	2. Net gain (loss) in gross earnings from jobs located or displaced by the freeway	Dollars	x	x
	3. Net increase (decrease) in job opportunities caused by expanded commuting area less jobs available to outside commuting	Number	x	x

the identifiable economic costs of accidents are considered on the monetary side of the ledger, and any attempt is avoided to place dollar values on loss of life, pain, or suffering caused by accidents. By the same line of reasoning, the authors recommend that discomfort, inconvenience, strain, and aesthetic considerations not be stated in money terms.

Factors in Community Impact—Table 2 gives a list of 18 factors that describe the community or nonuser effects of freeway route location. They are grouped into 4 areas: local transportation effects, community planning and environment, neighborhood and social structure, and community economic and fiscal structure. As indicated earlier, techniques are not available and may not be appropriate for expressing the community effects of freeways in money terms. Quantification of others may not be possible even in nonmonetary terms. Table 2 gives some possible measures for items that appear to be quantifiable. Some of these have been taken from the highway research literature; others are suggestions of the authors. All are tentative at this point.

The factors and suggested measures given in Table 2 can be used as a basis for evaluating differences in community impact of various alternatives. It must be recognized that those measures that are given in dollar values are not compatible with the market cost items in Table 1 and therefore cannot be incorporated into the economic analysis. Although the list of factors and measures given in Table 2 provides a reasonable means for identifying and measuring community effects, it is also meant to stimulate thought, research, and improvement in the means for describing and measuring community impact. Only by collecting data during route location studies and on the effects of existing freeways will it be possible to properly evaluate the community effects of proposed freeway route alternatives.

Viewpoint as a Factor in Evaluating Community Effects

Different alternatives affect the various levels of government, communities, and groups in different ways. Much of today's controversy over freeways results from the failure of one group to appreciate another's values and concerns.

To provide some insight into the principal concerns of the major decision-making groups, a research survey was used to evaluate the attitudes of planning and decision-making groups toward the factors in freeway route locations given in Table 1. The survey was conducted in 3 parts during September, October, and November 1968, and April, May, and July 1969. The first sample included 54 highway engineers and planners in the Los Angeles, San Francisco, and Sacramento offices of the California Division of Highways. The second was a sample of 160 community officials and professional staff including mayors, city councilmen, city managers, city engineers, and city planners. This sample was drawn from all the communities of the 2 major urban areas of California, San Francisco-Oakland, and Los Angeles-Orange County, where freeway studies were currently being or had been conducted in the 3 years from 1965 to 1968. The third was a sample of 123 citizens from 4 communities in an area of southern California where a freeway study was recently completed and a route selected. The communities were primarily suburban and residential in nature. A few of the results of the survey are given in Table 3. They show the degree of importance placed on route location factors by these 3 groups.

Several of the responses of the 3 groups deserve comment. First is the attitude toward vehicle operating costs. They are considered to be of importance by the highway planners; on the other hand, community officials or citizens place practically no

TABLE 3

IMPORTANCE OF FACTORS IN ROUTE LOCATION TO 54 HIGHWAY ENGINEERS AND PLANNERS, 160 COMMUNITY OFFICIALS, AND 123 CITIZENS

Factor	Percent of Highway Engineers and Planners			Percent of Community Officials			Percent of Citizens		
	Major	Minor	No	Major	Minor	No	Major	Minor	No
Direct costs and benefits of freeway									
Cost of highway	95	4	1	86	12	1	81	16	1
Motorist safety and comfort	85	13	2	84	12	2	87	8	1
Travel time savings	52	43	5	55	40	2	61	31	7
Vehicle operating cost	41	54	5	29	48	21	19	50	29
Local transportation effects									
Traffic service to city	96	4	0	89	8	1	77	20	1
Local transportation	74	20	6	91	7	2	63	31	4
Regional access	50	45	5	65	31	2	55	37	7
Highway design standards	93	5	2	87	11	2	81	16	1
Community planning and environment									
Land use plans	65	32	3	79	17	2	52	37	8
Aesthetics of freeway	69	26	5	76	21	1	42	51	2
Noise	24	67	9	67	28	3	51	42	4
Air pollution	13	52	35	58	33	6	72	22	2
Neighborhood and social structure									
Property values	65	28	7	72	22	2	59	33	6
Neighborhood impact	54	41	5	59	33	5	40	41	17
Parks and recreation	82	18	0	58	34	6	37	51	8
Cultural and religious centers	54	43	3	36	57	4	17	61	18
Historical and unique areas	69	30	1	64	32	2	37	48	11
School system	56	37	7	51	43	5	43	42	13
Community economic and fiscal structure									
Effect on tax base	30	61	9	49	42	7	48	41	7
Community services	32	65	3	71	25	2	61	34	3
Commercial activity	37	50	13	56	39	3	47	43	6
Employment	41	45	14	56	32	8	60	35	2

importance on them. Second, as expected, the highway planners show less concern for local traffic circulation than do city officials. Third, regarding the factors in community environment such as noise and air pollution, there is much more concern by community officials and citizens than by the highway planners. Finally, the factors reflecting neighborhood and social structure were of much less importance to this particular sample of citizens than to either the highway planners or community officials.

These few examples point out the need for considering the various viewpoints in planning studies. Based on the survey, the conclusion might be that, from the local viewpoint, highway planners are putting much more emphasis on parks, the effects on the school system, and cultural and religious institutions than is necessary. On the other hand, the results clearly indicate that, at least in this instance, some factors ranked as important by planners are not valued as highly by local officials and citizens. The factors that are most important will, of course, vary with each individual project. Some means, such as that given in Table 3, should be used to evaluate every project at the conceptual stage with each affected group expressing its principal concerns. Besides the groups included in this survey, other groups composed of school districts and commercial and industrial interests should also be considered. Identification of the factors of greatest concern to each community group might help in the identification of the costs and benefits and the points of agreement and disagreement. It should be emphasized that the purpose of such evaluation is to eliminate confusion and many of the pointless arguments, and not to assign weights to the factors for evaluation of alternatives.

Time Period

The time period over which the consequences of the various factors are evaluated is also important. Otherwise short-run consequences might be given more weight in the decision as compared to the long-run effects, or vice versa. For example, the community might be concerned that elderly people would be displaced from their homes in a given area. At the same time, the community master plan may indicate that the area is suitable for high-density apartments, and a survey may show that the transition is already under way. In this instance, an appreciation of the time factor is extremely important to a rational appraisal of the possible alternatives.

The columns on the right in Tables 1 and 2 provide space in which the time period can be expressed (in some manner) in order to bring each factor into focus. A decision-maker may on this basis be able to "discount" the significance of a factor's impact, conceivably in ways similar to the application of compound interest formulas in the economy study.

COMMUNITY FACTOR PROFILES: A DECISION-MAKING TOOL

The approach to decision-making among alternatives suggested earlier in this paper pointed out that correct decisions among freeway location alternatives must have 2 parts: (a) an economy study that includes all items that can be reduced to money terms and (b) an analysis of all items that cannot be stated in terms of money but that must be weighed in the decision. The approach proposed for analyzing the indirect or community effects of the second part has been called a community factor profile. In the opinion of the authors, this approach is at least a step toward more rational decision-making.

The community factor profile is a graphical description, based on the factors and measures given in Table 2, of the effects of each proposed freeway location alternative. Figure 1 shows a highly simplified and consolidated version of such a profile for 4 alternative locations. Each profile scale is on a percentage base, ranging from a negative to a positive 100 percent; 100 percent either negative or positive is the maximum absolute value of the measure that is adopted for each factor. Reduction to the percentage base simplifies scaling and plotting the profiles. The maximum positive or negative value of the measure, the units, and the time span are indicated on the right side of the profile for reference. For each alternative, the positive or negative value for any factor is calculated as a percentage of the maximum absolute value over all alternatives and is plotted on the appropriate abscissa. A solid line connecting the plotted

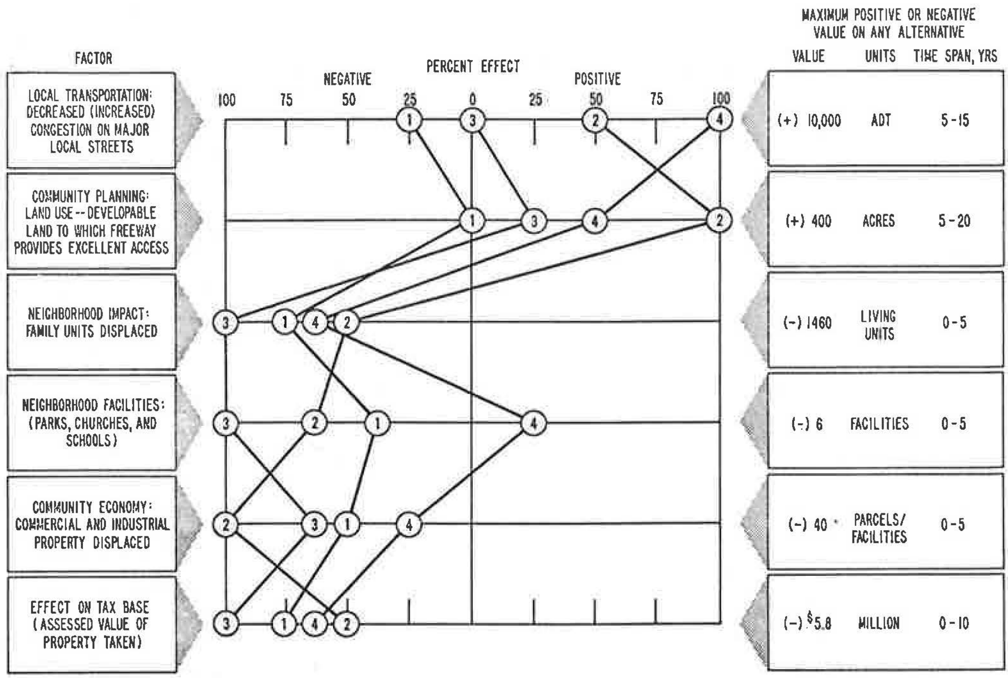

Figure 1. Community factor profile: Numbers in circles indicate the 4 alternatives.

points for each alternative gives its factor profile. For the profiles, factors and measures should be selected that will adequately describe all important elements of community impact. Care should be used in defining factor measures to ensure that they are not measuring the same consequences. Otherwise, in effect, there would be double counting, and disproportionate weight would be given to those factors. This may result in incorrect decisions.

In order to reduce the complexity of the diagram and, in turn, of the decision-making process, the full set of community factors should be reduced whenever it is possible to do so. Two guidelines are suggested for accomplishing this: (a) Eliminate all factors that are not relevant or important to the particular decision; and (b) eliminate all factors whose values are substantially the same for all alternatives. These tests must be acceptable to all parties involved in the study.

It is expected that the profiles will be prepared for each alternative from the viewpoint of each community interest group and will incorporate the factors that are important to that particular group's viewpoint. A composite profile would also be prepared showing the total community effect for each factor. Separate profiles for each alternative could be made on transparent overlays to facilitate the method of comparison proposed in the following section of this paper. In passing it should be noted that research is well under way to provide such displays on a cathode-ray tube activated by a computer. This would permit almost instant recall of any comparisons that seemed appropriate.

METHOD FOR PLAN EVALUATION

Because of the complexity that real-life factor profiles would often have, a systematic procedure for evaluating and comparing the relative merits of the several alternatives is essential. The method proposed here is that a series of paired comparisons be made using engineering economic analysis and factor profiles as the decision-making tools.

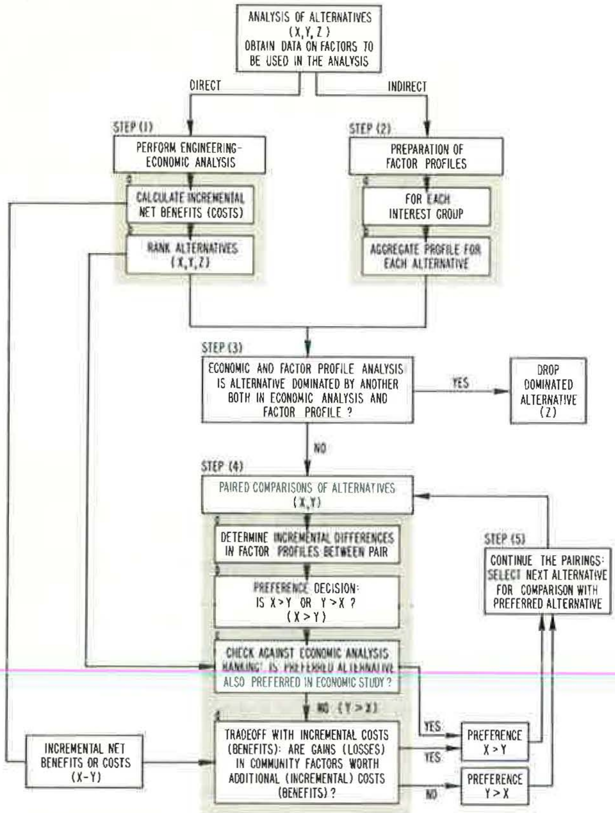

Figure 2. Method for comparisons among alternatives.

First, alternatives 1 and 2 would be compared; then the better of these is compared with 3, and so on. When 2 alternatives are compared, the incremental cost or benefit from the economic analysis is weighed against the differences in community impact between the alternatives as shown by the factor profiles. The decision-maker representing each group would appraise the economic and community factors and determine his preference between the 2 alternatives. After all the paired comparisons among the various alternatives have been completed, there would result preference rankings for each viewpoint in the community. These would be used for comparisons among competing viewpoints in reaching a final decision. [From the point of view of the science of decision theory, the paired comparison approach falls down when more than 2 parties are involved in the decision. However, this theoretical objection does not mean that the paired comparison approach will not work in the real world. This difficulty is widely discussed in the literature (15)].

A highly simplified example to illustrate the paired comparison approach is given by the question: "Is it preferable to save $50,000 per year in vehicle operating costs accruing to local residents by adopting a shorter route or to retain a commercial enterprise employing 10 people and paying $20,000 per year in property taxes? It is estimated that a substitute enterprise will develop in 5 years." It is admitted that this example is far simpler than those of the real world where the factor profile would include several elements. Even so, such comparisons make clear the actual points at issue and may greatly reduce the number of irrational arguments that accompany most controversial decisions.

Technique for Comparisons Among Alternatives

The flow chart shown in Figure 2 depicts the procedure to be followed in making the paired comparisons described earlier. Failure to follow some such procedure may result in selecting the less-than-optimum alternative.

Step 1: Engineering Economic Analysis—Rank the alternatives in order of preference as determined by the economic analysis. This may be done on the basis of maximum net benefits over cost or total and incremental benefit-cost ratios or rates of return. Tabulate the net benefits over costs for each alternative.

Step 2: Factor Profiles—Prepare factor profiles from the viewpoint of each interest group showing the freeway's impact on each relevant factor for that group. Prepare a factor profile also that shows the total or aggregate effect of each alternative over all communities and groups.

Step 3: Economic and Factor Profile Analysis—Compare alternatives on the basis of the economic analysis and the factor profiles. Eliminate from the set of feasible alternatives any alternative that is dominated by another from the standpoint of both the economic analysis and the factor profile. One alternative is strictly dominant over another if all percentage values of the factor profile of the dominant alternative are greater than that of the alternative. This implies that there are no crossovers in the lines of the factor profiles for the 2 alternatives.

Step 4: Paired Comparisons of Alternatives—Paired comparisons are made for each viewpoint on the basis of the incremental differences in community effects from the factor profiles and these are then compared with the incremental differences in costs from the economic analysis. Any 2 alternatives can be paired, but a reasonable beginning would be to pair one of the alternatives having a good factor profile with the preferred alternative from the economic analysis. (a) Determine the differences between the alternatives for the community factors, and compare the increments of values gained with the increments of values lost. (b) State a preference between the 2 alternatives based on the importance to the decision-makers of the trade-offs among the factors. (c) Check the preference statement against the ranking from the economic analysis. This resolves the question, "Is the alternative preferred in (a) also superior from the standpoint of the economic analysis?" If the answer is yes, then the preferred alternative is paired with the next alternative selected for analysis. If no, then the analysis proceeds to (d). (d) Test the differences in community factors against the excess of costs over benefits. The decision-maker is asking the question, "Are the gains in community factors worth the additional incremental costs of this alternative?" If the answer is yes, the alternative of higher cost is preferred because of its higher community benefits. Otherwise, the alternative preferred from the economic analysis is selected and paired against the next alternative for analysis.

Step 5: Continue Paired Comparison Procedure—Continue procedure (a) through (d) in step 4 until all feasible alternatives have been included in comparisons. The paired comparisons among the feasible alternatives produce a preferred alternative, and also a preference ranking among all alternatives for each viewpoint if this is desired.

The only constraint imposed on the decision-makers in the paired comparisons is that preferences among alternatives must be transitive; i.e., if A is preferred to B, and B is preferred to C, then A is preferred to C. This ensures that preferences and decisions are consistent with previous ones, and that the final ranking of alternatives reflects the decision-makers' true preferences.

In sum, the purpose of the factor profiles and the procedure for analysis is to help the decision-maker apply the 2 basic principles of decision-making: (a) to separate economic effects measurable in dollar values from other consequences and (b) to compare the differences in alternatives in making decisions. The factor profiles and the method of analysis offer both a visual aid and a systematic procedure for implementing these principles. The construction of the factor profiles does not imply that the area under the curves can be integrated, or the percentage values of factors can be added in order to make a decision. To do so would be to revert to the factor-weighting methods discussed earlier in this paper.

An Example Application

Consider a freeway route location with 4 proposed alternatives and with the relevant community impact factors and corresponding factor profiles shown in Figure 1. The economic analysis given in Tables 4 and 5 indicates that alternative 2 is preferred because it shows a benefit-cost ratio greater than 1 on the total investment and on all increments of investment. Alternative 1 ranks next, then 4 and 3 have equal desirability from an economic standpoint.

It must be recognized that the rankings given by this analysis can be changed substantially by changing the interest rate; lower rates will tend to favor higher capital investments. This example is based on an interest rate that reflects the minimum attractive rate of return for a particular highway agency.

In examining the factor profiles, we find that the profile of alternative 4 dominates both 1 and 3. Because 4 is equally as attractive as 3 in the economic analysis, alternative 3 can be dropped on the basis of the dominance tests. For the first paired

TABLE 4

COSTS AND BENEFITS OF LOCATION ALTERNATIVES

Item	Alternative 1	2	3	4
Annual cost, $	650,000	750,000	850,000	700,000
Annual road user savings, $	1,000,000	1,200,000	1,150,000	1,000,000
Net benefits, $	350,000	450,000	300,000	300,000
Benefit-cost ratio	1.54	1.60	1.35	1.43

comparison, alternative 2, preferred from the economic analysis, is paired with 4, a dominant alternative from the factor profiles. In comparing the differences between these two alternatives, we find that alternative 2 provides 200 acres of developable land and saves 290 housing units and $0.58 million in assessed valuation. On the other hand, alternative 4 decreases the average daily traffic on major local streets by 5,000 vehicles and saves 25 parcels of industrial property and 2 community facilities. Let it then be assumed that the decision-makers agree that alternative 4 is the more attractive of the two, based on the factor analysis trade-offs.

In the economic analysis, however, alternative 2 is preferred to 4 by $150,000 per year, so that additional comparison with the net benefits foregone must also be made. Here it should be noted that alternative 2 costs the agency that will build the freeway $50,000 more per year; on the other hand, vehicle operating costs are $200,000 per year less. It could be that the various groups would therefore weigh the economic consequences quite differently. If it is assumed that, even with the cost differences, alternative 4 is selected over 2, a similar comparison would be made between alternatives 4 and 1.

ADVANTAGES OF THE PROPOSED APPROACH

When a composite analysis of the overall effects of route location alternatives does not produce a final decision among alternatives because of conflicts of interest among decision groups, then an analysis of factor profiles from the viewpoint of each decision-making group can be performed. If those factors that are relevant to each decision-making group are separated and the procedure for analysis shown in Figure 2 followed, a preference ranking of alternatives can be derived for each viewpoint. The rankings and profiles can then be used for resolving conflicts among competing interest groups. In addition, where there are areas of disagreement, the factors responsible for such conflicts, and the reasons for them, can be pinpointed explicitly.

The proposed approach can also serve as a basis for negotiation and compensation. In a political setting, arriving at decisions that are as equitable as possible may involve negotiation and compensation of losers by the gainers. One of two approaches can be taken by decision-makers in arriving at final decisions: (a) selecting the alternative that will distribute the impact as equally as possible among the conflicting interest groups, and (b) selecting the alternative that maximizes the net benefits of both economic and community factors along the entire route. With either approach the factor profiles can be used as a basis for negotiation and bargaining, and for determining and providing for compensations to communities, groups, and individuals to achieve equitable solutions. This becomes especially important in the light of new and proposed legislation

TABLE 5

INCREMENTAL ANALYSIS

Alternative	Incremental Cost, $	Incremental Benefit, $	Benefit-Cost Ratio	Incremental Net Benefit (Cost), $
4 over 1	50,000	0	0	(50,000)
2 over 1	100,000	200,000	+2.0	100,000
3 over 1	200,000	150,000	+0.75	(50,000)
2 over 4	50,000	200,000	+4.0	150,000
3 over 4	150,000	150,000	+1.0	0
3 over 2	100,000	(50,000)	-0.5	(150,000)

respecting public hearings, decisions, and compensation for losses. Recently, the courts have altered the concept of compensating property to one of compensating people when freeway rights-of-way are acquired. It is not a great step to the concept of compensating communities and groups for losses resulting from freeways. At the same time, provisions might be made to allow communities and groups to make certain concessions and side payments, and adjust community and service district boundaries in order to equalize gains and losses. Such steps as these could do much to smooth the present rocky road to agreements on freeway locations.

SUMMARY

A summary of the advantages of the proposed factor analysis method for evaluating freeway locations follows:

1. It separates the direct money consequences from the community consequences so that they do not become confused in the analysis.
2. In complex decision-making where it is important to have more rather than less information on which to base the decisions, it provides a means by which to display the different factors relevant to making choices.
3. It provides a means for comparing the incremental differences in community factors among alternatives and for contrasting them with the differences in economic costs or benefits.
4. It also provides for separation of viewpoints as well as an analysis of the overall impact. It shows the incidence of community effects on community groups, brings out the points of agreement or disagreement among those groups, and serves as a mechanism in resolving those conflicts.
5. Finally, factor identification and factor profiles can be useful tools during the planning process in defining the factors that are important to the community and community groups, in establishing goals and objectives, in serving as a basis for discussion during the development of alternatives, and in evaluating and making decisions among alternatives.

REFERENCES

1. Curry, D. A. Use of Marginal Cost of Time in Highway Economy Studies. Highway Research Record 77, 1965, pp. 48-120.
2. Fleischer, G. A. Effect of Highway Improvement on Travel Time of Commercial Vehicles: A Twenty-Five Year Case Study. Highway Research Record 12, 1963, pp. 19-47.
3. Grant, E. L., and Ireson, W. G. Principles of Engineering Economy. Ronald Press, N.Y., 4th ed., 1964, pp. 21-23, 436, 445-448, 456.
4. Grant, E. L., and Oglesby, C. H. Economy Studies for Highways. HRB Bull. 306, 1961, pp. 23-38.
5. Glancy, D. M. Utilization of Economic Analysis by State Highway Departments. Highway Research Record 77, 1965, pp. 121-132.
6. Haney, D. G. Use of Two Concepts of the Value of Time. Highway Research Record 12, 1963, pp. 1-18.
7. Hill, M. A Method for the Evaluation of Transportation Plans. Highway Research Record 180, 1967, pp. 21-34.
8. Jessiman, W., et al. A Rational Decision-Making Technique for Transportation Planning. Highway Research Record 180, 1967, pp. 71-80.
9. Roberts, P. O. Transportation Research Forum, 7th Annual Meeting, 1966, pp. 169-183.
10. Schlager, K. The Rank-Based Expected Value Method of Plan Evaluation. Highway Research Record 238, 1968, pp. 153-158.
11. Shimpeler, C. C., and Grecco, W. L. Systems Evaluation: An Approach Based on Community Structure and Values. Highway Research Record 238, 1968, pp. 123-152.

12. Thomas, T. C. Value of Time for Commuting Motorists. Highway Research Record 245, 1968, pp. 17-35.
13. Winfrey, R. Economic Analysis for Highways. International Textbook Co., Scranton, Penn., 1969.
14. Hill, S. L., and Frankland, B. Mobility as Measure of Neighborhood. Highway Research Record 187, 1967, pp. 33-42.
15. Luce, R. D., and Raiffa, H. Games and Decisions. John Wiley and Sons, 1957.

Discussion

HAROLD HANDERSON, Office of High Speed Ground Transportation, U.S. Department of Transportation—This paper presents a means for displaying monetary and other impact factors that differentiate previously identified transportation facility location alternatives. As the authors suggest, this has advantages both for planning and for resolving intergroup conflicts, depending on how the procedure is used.

The authors should be more careful, however, in setting forth the limits to the utility of this methodology. For example, I probably would not be amiss to remind the reader of the following points:

1. The methodology assumes that some new transportation route is at least worth considering, although it is theoretically possible that none of the predetermined route alternatives will prove acceptable (stated on pp. 6-9 of the report of Project 13469 to the California Division of Highways, on which this paper is based);
2. The methodology assumes that the alternatives generated for analysis contain the "best" possibility in terms of the desired objectives; and
3. The methodology does not ensure that the proper categories will be used in the analysis—though the process can be self-correcting, particularly if used generally and publicly (as, for instance, the criteria suggested in the Bureau of Public Roads Policy and Procedures Memorandum 20-8 of January 14, 1969, on public hearings and location approval).

The 2 decision approaches, which the authors say in the final subsection of their paper can be taken, are faulty:

1. An alternative to "equal" distribution of impacts is "equitable" distribution—less precise, but more worthy of attention in a public program.
2. It is highly doubtful that any alternative will maximize the net benefits of both "economic and community factors along the entire route." It is more likely that the relative distribution of benefits will be the key factor in a public decision process.

Of course, public officials have a responsibility to educate the general citizenry and promote its welfare, as well as to be responsive to its concerns at any given time. To perform this set of tasks requires considerable work to determine the particular impact categories and weighting factors that should be used in practical applications of this method. This is clear from the brief survey of concerned groups in the section "Viewpoint as a Factor in Evaluating Community Effects." Application of these ideas should be given high priority by all concerned groups, particularly because the current Interstate highway program still provides some possibilities for immediate application of findings in long-term facility decisions.

C. H. OGLESBY, BRUCE BISHOP, and G. E. WILLEKE, Closure—Mr. Handerson's thoughtful discussion is much appreciated. Comments such as his do much to clarify points that authors omit or do not make clear.

He first indicates 3 points where he feels the authors should be more careful. First he notes that it is possible that none of the predetermined route alternatives will prove acceptable. If this is indeed the case, there are at least 2 courses of action: (a) to do nothing and (b) to present an additional alternative or set of alternatives. A third possibility that may be entertained is the change of the standards of acceptability by the ultimate decision-makers, whoever they may be. Doing nothing is always among the feasible solutions. The other courses of action may or may not be. They certainly presume the necessity of iterative planning.

Mr. Handerson's second point is based on the presumption that the approach offered in the paper presents only choices among the "best" alternatives. This can never be the case in the real world where many solutions, each with its set of subsolutions, can be developed. At best, the approach put forward in the paper will define only the major controls for each proposed location, after which highway planners will fit appropriate details to it. In actual situations, some of the steps in the suggested procedure might have to be employed before agreement is reached on some of these details. Then, given a set of alternatives, the proposed methodology provides a basis of choosing the "best" alternative of that set.

The third point is that the categories proposed for evaluating freeway impacts may not be the proper ones. This is most certainly true. However, those offered in the paper were developed after a detailed literature search and several months of consultation with highway planners. They therefore represent a good starting point. But each planning group would, of necessity, either add to or deduct items from that suggested list as agreements or disagreements develop during the study period.

Mr. Handerson quarrels with the choice of words used in the 2 "decision approaches" suggested in the final subsection of the paper. He feels that they imply a precision in the decision process that is not possible in real-life situations. It was not the authors' intent to suggest that precision would ever be possible in a political setting. In any event, the less precise wording proposed by Mr. Handerson should certainly be used by those who feel that the approaches as stated are too restrictive.

It should also be pointed out that if economic and community factors are not expressed in common units, a premise of the paper, there is no real difference between the relative distribution of benefits and maximizing the sum of net benefits of economic and community factors. The decision approach on these grounds is not faulty, unless misinterpreted by the user.

In sum, Mr. Handerson's comments reinforce the authors' argument that much can and should be done to get greater public involvement in decisions regarding freeway locations and thereby to improve those decisions.